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(72) Inventor PER KAIN

(54) MEANS FOR WORKING MATERIALS, FOR EXAMPLE ROLLING MILLS

(71) We, ALLMANNA SVENSKA ELEKTRISKA AKTIEBOLAGET, a Swedish Company, of Västeras, Sweden, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a means for working material in which properties of the material are measured upstream and downstream of a working member, such as one or more pairs of rolls in a rolling mill, the working process being arranged to be regulated by one or more signals from measuring points situated upstream and downstream of the working member.

When working material to desired dimensions (thickness, width, diameter, etc.), each dimension is normally measured after the working process. The error, with respect to desired and measured values for each dimension influences the working member in such a way that the error is eliminated ("feed-back"). If the conditions are static, i.e. if no alterations occur in the material arriving to undergo the working process or in the working process itself, material is obtained after a while which has the desired dimensions. However, as this is only an ideal case which very seldom occurs in practice and as the dimensions of the arriving material usually vary, corresponding deviations occur in the material leaving the working member until a feed-back control has come into operation.

In order to obtain better agreement with the desired dimensions of the material after the working process, even under dynamic conditions, the material entering the working member is often measured and alterations in these dimensions are permitted to influence the working process in such a way that errors with respect to the desired dimensions after working are eliminated. This control method is called here "feed-forward" control and it is important that the timing and strength of the control are correct. The timing must be such that alterations in the working process are initiated at the same time as the material which was measured upstream of the working member actually passes said member. Account must be taken of the measuring time, of the time taken by the material to pass from the measuring point to the working member and of the time taken in the working process to effect certain alterations in dimension. The strength of the control must be such that an alteration in the properties of the arriving material effects such an alteration in the working process that no errors with respect to the desired dimensions of the material leaving the working process arise. One problem in this type of control is that it is difficult to measure alterations in all the dimensions of the material as it arrives at the working member.

The present invention seeks to provide a development of the "feed-forward" principle which overcomes the problems mentioned.

According to the invention, means for working material in which at least one property of the material is measured upstream and downstream of a working member, the working member being provided with control means controlled by output signals from the measuring means upstream and downstream of said member, is characterised in that a measured value and a reference value for one of said properties are compared in each of said measuring means, the output signal from each of said measuring means being the deviation or error between said measured and said reference value, and in that the output signal from the upstream measuring means, after correction for time difference corresponding to the transport time of the material between the upstream and downstream measuring means, is combined with the output signal from the downstream measuring means in a signal treating device, the output signal from which is fed to a correct device, the output signal

[*Price 25p*]

from which is fed to control devices for the working member.

Particularly advantageous conditions are achieved with a preferred embodiment where at least two measured values are compared with at least two reference values, the two or more deviations or errors thus produced being combined into a comparison or output signal for each measuring means, a first comparison signal for the upstream measuring means and a second comparison signal for the downstream measuring means. The comparison signals are fed to an alteration device, the first comparison signal over a time delay device, the output signal from said alteration device being fed to the correction device.

The invention will now be described in greater detail, by way of example, in connection with a rolling mill and with reference to the accompanying drawings. However, the invention can be applied to other material working means, for example drawing machines, milling machines, rod mills, etc.

In the drawings:—

Figure 1 is a schematic view of part of a rolling mill having a roll pair and control devices,

Figure 2 is a graph illustrating aspects of the process during rolling, and

Figures *3a—d* are circuit diagrams of parts of the rolling mill of Figure 1.

Figure 1 shows a roll pair 11 with support rollers 12, forming part of a rolling mill having one or more roll stands or roll pairs. The roll pair 11 is provided in conventional manner with a screw 13 and a screw motor 14 for altering the rolling gap. The rolling mill is intended for the cold or hot rolling of sheet 15, or wire coming from a reel 16 and leading to a reel 17. For convenience in the ensuing description the material being rolled will be referred to as "strip".

Upstream of the roll pair 11, which constitutes the aforesaid working member, there is arranged at least one measuring means 18 for measuring a parameter (e.g. thickness or width) of the strip and at least one similar measuring means 19 is arranged downstream of the roll pair 11. Each measuring means 18 and 19 measures the deviation or error between a measured value and a reference value of the strip parameter to be controlled. Preferably several measurements of deviation or error, for each measuring means, are made at intervals of time at a point along the control path of the strip. These measurements are combined into a comparison signal forming the output signal of a measuring means. The output signal from the measuring means 19 is supplied to a regulator 27. The output signal from the measuring means 18 is delayed at 26 for running time, measuring time and control time, after which both output signals from said measuring means are supplied via a signal treating device 28 to a correction device 22.

The output signals from the measuring means 18 and 19 are preferably supplied to an alteration device 20 where they are compared and converted into another signal as described below, the output signal from the measuring means 18 being supplied via a time-delay device 21 to be delayed for the running time of the strip from the measuring means 18 to the measuring means 19. The output signal from the device 20 is combined in the correction device 22 with the output signal from the signal treating device 28. The output from the device 22 is a correction signal which is supplied to a control device for the screw motor 14, and/or to a control device 25 for the rolling mill motor, and/or to devices 23, 24 for controlling the reels 16, 17 to regulate the strip tension.

It is also possible to regulate the various parameters of the strip being rolled (for example, thickness, speed, track tension, temperature) separately in separate control circuits and, by means of sampling, to combine said "feed-forward" control with normal "feed-back" control so that these two types of control can operate independently of each other.

The aim is to alter the correction signal constituting the output of the correction device 22 as far as its strength is concerned. Thus, if there is a substantial change in the output signal from the measuring means 19 or a substantial alteration of the error signal from the measuring means 18, the strength of the correction signal should be altered.

The alteration device 20 produces an output put signal having a value which is obtained by forming a relationship *a* between the alteration of the errors downstream of the rolling gap and the difference between the alterations of the errors upstream of the rolling gap and the alteration of the errors downstream of the rolling gap. The relationship *a* which should be included in the correction signal from the correction device 22 is given by the equation:—

$$a = \frac{\Delta_{ut2} - \Delta_{ut1}}{\Delta h_{in2} - \Delta h_{in1} - (\Delta h_{ut2} - \Delta h_{ut1})}$$

where Δh_{in} is the error upstream of the rolling gap and Δh_{ut} is the error downstream of the rolling gap and $\Delta h_{ut2} - \Delta h_{ut1}$ and $\Delta h_{in2} - \Delta h_{in1}$ are the alterations in the errors downstream and upstream of the rolling gap, respectively. As mentioned, this relationship *a* should be used to correct the strength of the correction signal.

Correction of the signal strength may be carried out by adding an extra value to the original value of the signal strength, for example in the correction device 22, or by

multiplying the original value of the signal strength by a certain factor, for example in the correction device 22, or both.

In the curve according to Figure 2 the ordinate relates to rolling pressure of the roll pair and the abscissa to alterations in thickness (Δh_{in}) of the strip upstream of the rolling gap and alterations in rolling gap (ΔS) of the roll pair, respectively. Q in Figure 2 is the hardness of the material and C is the strain of the roll stand. The relationship between rolling pressure-rolling gap and thickness alteration-rolling pressure can be seen from this curve. According to Figure 2 the following is obtained:

$$\frac{d}{c} = Q_1 \qquad \frac{b}{c} = C$$

$$\begin{cases} \dfrac{d+b}{\Delta S_1} = C \\[2ex] \dfrac{d+b}{\Delta h_{in}} = Q_1 \quad \dfrac{\Delta h_{in}}{\Delta S_1} = \dfrac{C}{Q_1} \quad \Delta S_1 = \dfrac{Q_1}{C}\Delta h_{in} \end{cases}$$

It may be assumed that the set value of the strength of the "feed-forward" signal is equal to

$$\frac{Q}{C},$$

that is ΔS will be equal to

$$\frac{Q}{C} \cdot \Delta h_{in}$$

where Δh_{in} is the alteration in entering thickness and Q the expected hardness of the material.

If it is assumed that the hardness is instead Q_1 and that an entering thickness alteration is Δh_{in}, then: the "feed-forward" signal (22—25) gives a rolling gap alteration ΔS which corresponds to a thickness correction Δh_{ut1} on the leaving strip. Without any control the thickness alteration would have been Δh_{ut2}. Thus the remaining thickness alteration is equal to $\Delta h_{ut2} - \Delta h_{ut1}$ ($= \Delta h_{ut}$). Thus:

$$\Delta S = \frac{C+Q_1}{C} \cdot \Delta h_{ut1} = \frac{Q}{C} \Delta h_{in}$$

$$\Delta S_1 = \frac{C+Q_1}{C} \cdot \Delta h_{ut2} = \frac{Q_1}{C} \cdot \Delta h_{in}$$

where ΔS_1 is the desired new screw movement. Furthermore:

$$\Delta S_1 - \Delta S = \frac{C+Q_1}{C} \cdot \Delta h_{ut} = \frac{Q_1 - Q}{C} \cdot \Delta h_{in}$$

In order to alter the strength from

$$\frac{Q}{C}$$

to

$$\frac{Q_1}{C}$$

the following correction is required:

$$\frac{Q_1}{C} = \frac{Q}{C}(1+a)+a$$

where

$$a = \frac{\Delta h_{ut}}{\Delta h_{in} - \Delta h_{ut}}$$

The relationship a according to the above is multiplied by the original signal strength value

$$\frac{Q}{C}$$

and this product is added to the relationship, and this extra value,

$$a \cdot \frac{Q}{C} + a,$$

is thus added to the original value. During correction of the strength of the correction signal, both the sign and the amplitude of the mathematical equation must be taken into consideration, thus for example the sign and amplitude of a.

The output signals upstream of the rolling gap from the measuring means 18 and downstream of the rolling gap from the measuring means 19 are compared by delaying the output signals from the measuring means 18 (in the device 21 and/or the device 26) by a length of time corresponding to the running time of the strip from the measurement upstream to the measurement downstream of the rolling gap, after which a comparison between these signals is made and a correction carried out on the strength of the correction signal.

Figures 3*a*—*d* show different details of the arrangement according to Figure 1. The screw motor 14 with its control means is shown in Figure 3a. A pulse emitter 29 comprising a

disc 30 with slots, which is rotated by the roll screw 13, lamps and photoelectric means emits pulses to a control amplifier 31 preceded by a digital to analogue converter and at 22 the signal comes in from the correction device 22 in Figure 1 and the output signal is fed to the screw motor 14. This control circuit is fed back in the normal manner.

Figure 3*b* shows the device 20 of Figure 1, this having the purpose of giving a certain relationship a given by the equation:—

$$a = \frac{\Delta h_{ut}}{\Delta h_{in} - \Delta h_{ut}}$$

To a summation device 32 are fed Δh_{in} and Δh_{ut}, the output signal of which is $\Delta h_{in} - \Delta h_{ut}$, which signal is fed to a potentiometer 33 (or the like) where this signal is multiplied by a (=adjustment of the potentiometer arm). The output from the potentiometer 32= $a\ (\Delta h_{in} - \Delta h_{ut})$ is fed to a second summation device 34, the output of which is

$$a(\Delta h_{in} - \Delta h_{ut}) + \Delta h_{ut}.$$

If this signal is zero

$$a = \frac{\Delta h_{ut}}{\Delta h_{in} - \Delta h_{ut}}$$

and to the motor amplifier 35 is fed said output signal and the potentiometer 33, ganged to potentiometer 33′ is adjusted so that the output to device 22 is a.

Alternatively, the device 20 may be a computer with the inputs Δh_{in} and Δh_{ut} and the output a.

Figure 3*c* shows the device 28 with the input signals coming from the devices 26 and 27 and comprising a summation device and a selector which determines which one of the outputs from 22 should be employed, perhaps one, two or three of them. The device 27 may be a proportional integrating amplifier or regulator of a well known kind and the device 26 may be a so-called shift register comprising an analogue-digital transducer, from which pulses are fed into the register where the counting is stopped and restarted in line with a delay frequency and from which the remaining pulses are fed to a digital-analogue transducer. The delay frequency is chosen with respect to running time for the rolled strip, measuring time at the measuring means 18 and regulation time.

The device 21 may be the same as the device 26 but the delay frequency is chosen only with respect to the running time.

The measuring means 18 and 19 may be gauges of X-ray type with references, and thus the output signals may be the difference between actual and desired gauge.

From the device 22 small signals may be sent to 23 and/or 24 (control means for the coiling motors) and larger signals to device 14 and/or device 25.

The correction device 22 may be a computer for obtaining an output signal

$$\frac{Q}{C}(1+a)+a$$

(see above). It may also be as shown in Figure 3*d*. From a constant voltage E_k a signal

$$\frac{Q}{C}$$

is taken out from a potentiometer 37 and at π this signal

$$\frac{Q}{C}$$

is multiplied by a. This signal

$$\frac{Q}{C}.a$$

is added at the summation device 38 to a and at the summation device 39 to

$$\frac{Q}{C},$$

the output from the last-mentioned device 39 thus being

$$\frac{Q}{C}(1+a)+a.$$

This signal is fed via an amplifier 40 to a servo-motor 41 which adjusts the potentiometers 37 and 37′ in such a manner that the desired correction is obtained in the device 22.

WHAT WE CLAIM IS:—

1. Means for working material in which at least one property of the material is measured upstream and downstream of a working member, the working member being provided with control means controlled by output signals from the measuring means upstream and downstream of said member, characterised in that a measured value and a reference value for one of said properties are compared in each of said measuring means, the output signal from each of said measuring means being the deviation or error between said measured and said reference value, and in that

the output signal from the upstream measuring means, after correction for time difference corresponding to the transport time of the material between the upstream and downstream measuring means, is combined with the output signal from the downstream measuring means in a signal treating device, the output signal from which is fed to a correction device, the output signal from which is fed to control devices for the working member.

2. Means according to claim 1, characterised in that for each measuring means at least two measured values are compared with at least two reference values, the two or more deviations or errors thus produced being combined into a comparison or output signal for each measuring means, a first comparison signal for the upstream measuring means and a second comparison signal for the downstream measuring means, and in that said comparison signals are fed to an alteration device, the first comparison signal over a time delay device, the output signal from said alteration device being fed to the correction device.

3. A rolling mill according to claim 2, in which the alteration device produces an output signal, the value of which is given by the relationship,

$$a = \frac{(\Delta h_{ut2} - \Delta h_{ut1})}{(\Delta h_{in2} - \Delta h_{in1}) - (\Delta h_{ut2} - \Delta h_{ut1})}$$

where $(\Delta h_{ut2} - \Delta h_{ut1})$ is the difference between the deviations or errors downstream of the working member, $(\Delta h_{in2} - \Delta h_{in1})$ is the difference between the deviations or errors upstream of the working member, and $_1$ and $_2$ refer to the two different comparisons of a measured value and a reference value, two before and two after the working member.

4. A rolling mill according to claim 2, in which the output signal of the correction device is fed to a control device for the working member, the strength of the output signal of the correction device being affected by the value of the output signal from the alteration device.

5. A rolling mill according to claim 2, in which the strength of a proportion

$$\frac{Q}{C}$$

of the output signal of the signal treating device is altered in the correction device by the addition of a first value to said proportion, the signal formed from said addition being the output signal of the comparison device.

6. A rolling mill according to claim 5, in which said first value comprises the sum of the product of the magnitude of the relationship a and said proportion

$$\frac{Q}{C}$$

and the relationship itself, said sum given by

$$\left(\frac{Q}{C} \cdot a + a\right),$$

a having the meaning recited in claim 3.

7. A rolling mill according to claim 4, in which the strength of the output signal of the correction device is affected by both the sign and the amplitude of the output from said alteration device.

8. A rolling mill according to claim 2, in which the rolling mill is arranged to be influenced by several parameters, such as roller gap, strip tension, speed and/or temperature during rolling, the control according to the various parameters being carried out independently of the control of any other parameter.

9. Means according to claim 1, in which a feed-forward control is arranged to be combined with a feed-back control in such a way that simultaneous operation of said two controls is prevented.

10. A rolling mill constructed and controlled substantially as herein described with reference to the accompanying drawings.

J. Y. & G. W. JOHNSON,
Furnival House,
14—18, High Holborn,
London, WC1V 6DE.
Chartered Patent Agents,
Agents for the Applicants.

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Fig. 1

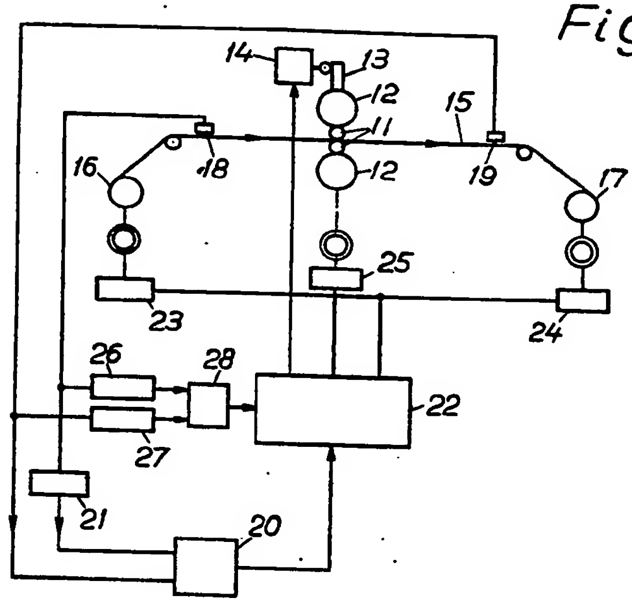
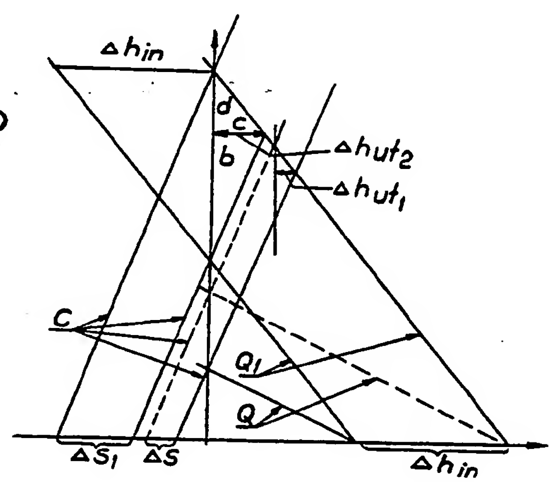

14
13
12
15
11
16
18
12
19
17
25
23
24
26
28
22
27
21
20

Fig. 2


Δhin
d
c
b
Δhut2
Δhut1
C
Q1
Q
ΔS1
ΔS
Δhin

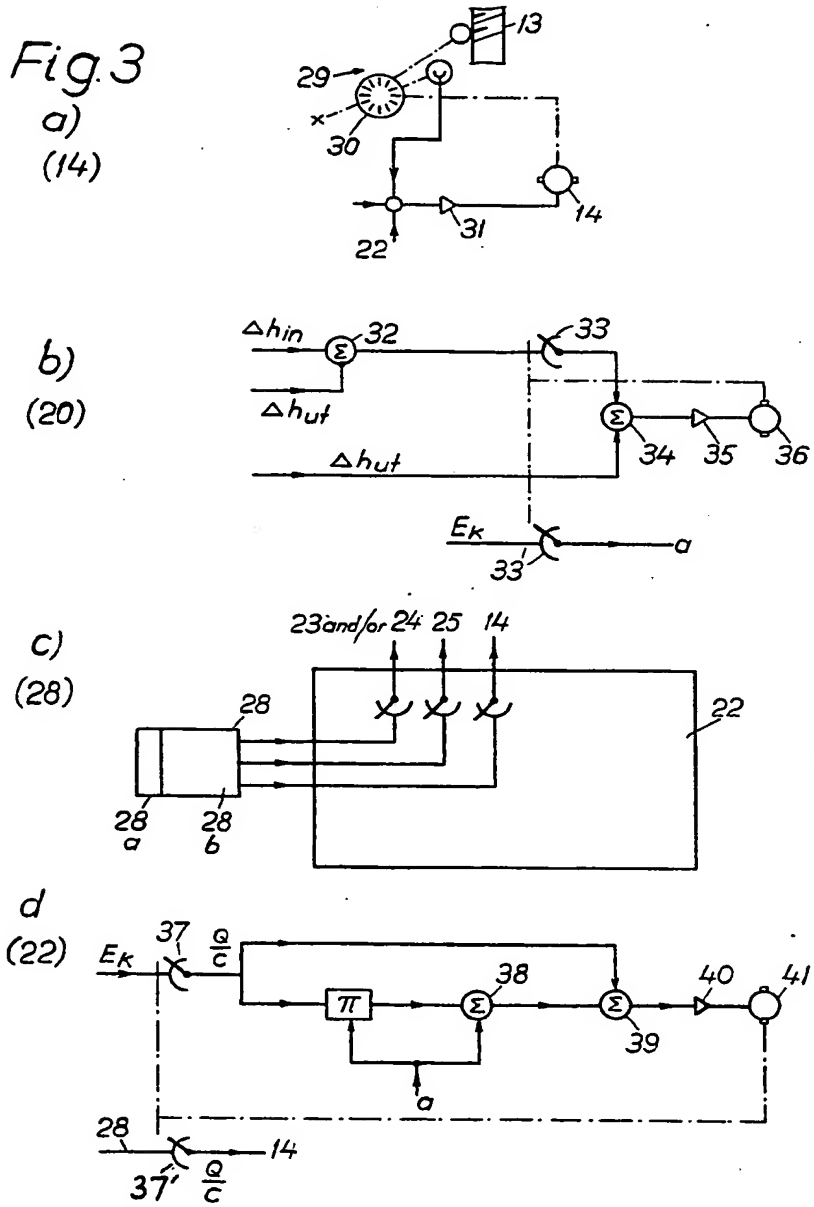


Fig.3
a)
(14)
13
29
30
x
14
31
22
b)
(20)
Δhin
32
33
Δhut
34
35
36
Δhut
EK
33'
a
c)
(28)
23 and/or 24
25
14
28
22
28 a
28 b
d
(22)
EK
37
Q/c
π
38
39
40
41
a
28
14
37'
Q/c